Manual No. 14-6628-A
February 1969

INSTRUCTION MANUAL

for

QSA SERIES

DUAL-RANGE POWER SUPPLIES

(MODELS 5-14.6 and 5-18.2)

RAYTHEON
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14-6628A-1
March 1969

ERRATA SHEET
INSTRUCTION MANUAL
QSA SERIES
Dual-Range Power Supplies

Page 2-2 Delete Note at top of page

Page 2-2 Delete last sentence of Note at bottom of page

Page 3-9 Delete paragraph 3-22 and Table 3-1 and replace with the following:

3-22 When operating units in series, rectifiers, mounted on heatsinks, must be connected across the individual unit outputs. Table 3-1 lists the recommended rectifiers and heatsinks. It is assumed that one forward and one reverse polarity rectifier will be mounted on each heatsink. If not, a separate heatsink must be used for each rectifier.

QSA MODEL	MANUFACTURER	MFR PART NO.	SORENSEN PART NO.
5-14.6	Westinghouse	409A/AR	26-1096-1/9
5-18.2	Westinghouse	417A/AR	26-1094-1/9

Table 3-1. Rectifier Recommendations, Series Operation

Heatsink Dimensions (1/32" aluminum):
5-14.6 4¼" x 4¼" 5-18.2 3½"x 3½"

Page 3-12 Delete Figure 3-4 and replace with the following corrected diagram (Note that terminals #1 and # 2 of both terminal boards are used for parallel operation.

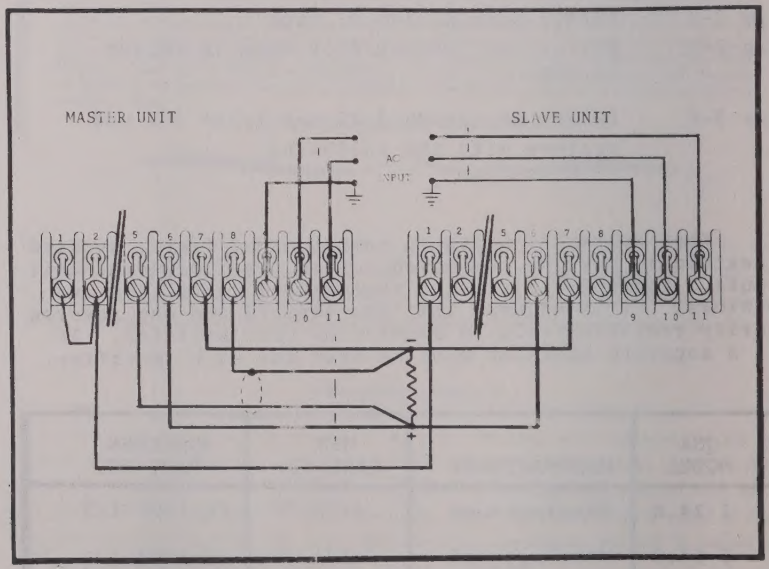

Figure 3-4. Parallel Operation

Voltage Regulation: ±0.005% for line and load changes combined.

Low ripple: 300uVrms (3mV peak to peak).

10u sec Crowbar Overvoltage Protection available for all models.

Thermally protected and short circuit proof (current limiting).

Meets MIL environment specifications.

No external heat sink or forced air required (to 71°C).

May be operated in any plane (tapped holes on three mounting surfaces).

All models are rack mountable in optional rack adapters with meter panels (up to four modules per adapter).

Maximum current available at all output voltage levels.

No turn on/turn off overshoots.

Remote sensing.

Remote programming by resistance and voltage.

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SECTION I

INTRODUCTION AND DESCRIPTION

1-1 INTRODUCTION.

1-2 This manual contains operating and maintenance instructions for the QSA 5-14.6 and 5-18.2 Dual-Range-voltage-regulated power supplies, manufactured by Raytheon Company, Sorensen Operation, Norwalk, Connecticut.

1-3 The manual is comprised of six major subdivisions which include a general description of the unit, preparation and operating instructions, principles of operation, and maintenance and troubleshooting procedures. The last section contains a complete replacement parts list including component description and manufacturer part numbers. It is suggested that the user familiarize himself with this manual before placing the unit in service.

1-4 DESCRIPTION.

1-5 The units provide a highly regulated d-c output in two ranges (3-4.5V and 4.5-6.5V) with any of three single phase inputs. They feature extremely fast recovery times and characteristically low output impedance. Table 1-1 gives a complete list of operating specifications.

1-6 REMOTE CONTROL. As shipped, adjustment of the output voltage of either supply is local, i.e., accomplished by a control located on each supply. Likewise, voltage regulation is local: the voltage regulator circuits hold the power-supply terminal voltage constant (within the specified tolerance). Relatively long leads between the power supply and load may allow the load-terminal voltage to fluctuate more than desired. Simple wiring changes and additions will allow the voltage output to be controlled (programmed) by either resistance control or

signal-voltage control. Equally simple changes may be made to regulate the voltage actually applied to the load, rather than that across the supply terminals.

1-7 DUAL VOLTAGE RANGES. Both supplies have high and low output-voltage ranges. They are normally wired at the factory for high-range output, but may be readily converted to low-range output by minor wiring changes.

1-8 SERIES OPERATION. When greater system output voltage is required, two units may be connected in series to provide the necessary output.

1-9 PARALLEL OPERATION. For applications requiring current higher than a single unit is capable of providing, QSA supplies may be connected in parallel. For a discussion of the number of units which may be used in this manner, refer to paragraph 3-24.

1-10 OVERLOAD PROTECTION. Both power supplies include overload-protection circuits. If the load tends to draw more than a predetermined maximum current, the output voltage and current are both reduced by a current foldback circuit.

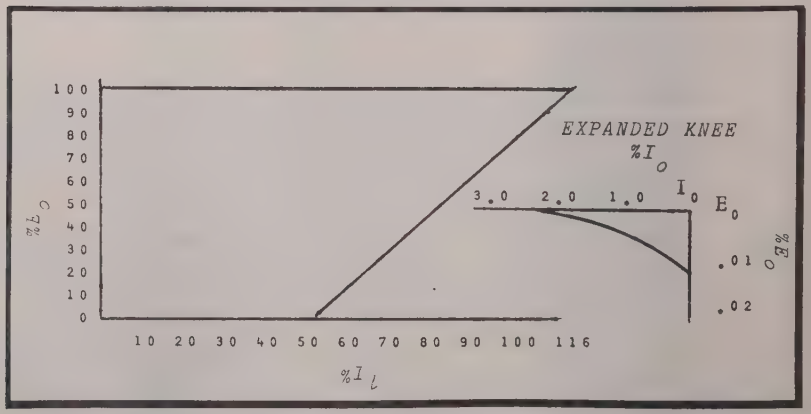


Figure 1-1. Current Foldback Characteristics (typical)

1-11 MOUNTING. The power supplies may be mounted on end, bottom, or side, using tapped holes in their enclosures. The enclosures not only provide protection for circuitry inside, but also serve as heatsinks, eliminating the need for external heatsinks. Note (see Figure 1-2) that maximum current depends on the mounting position.

1-12 OPTIONAL ACCESSORIES.

1-13 Two rack-mounted adapters, types SR3 and SR4, are offered as optional accessories to the QSA line. Both are designed for standard 19-inch relay racks and both are 5-1/4 inches in height. Either will hold two power supplies - in any combination - of the two models described here. Both adapters provide for mounting optional meter-panel and/or over-voltage accessories. (see Figure 1-3), and both have optional screw-mounted front panels which add to the appearance of the installation while still allowing ready access to the units if terminal-board alterations are necessary. In addition, the SR4 construction allows units to be mounted at the front or rear of the adapter and incorporates optional relay-rack slides at each side.

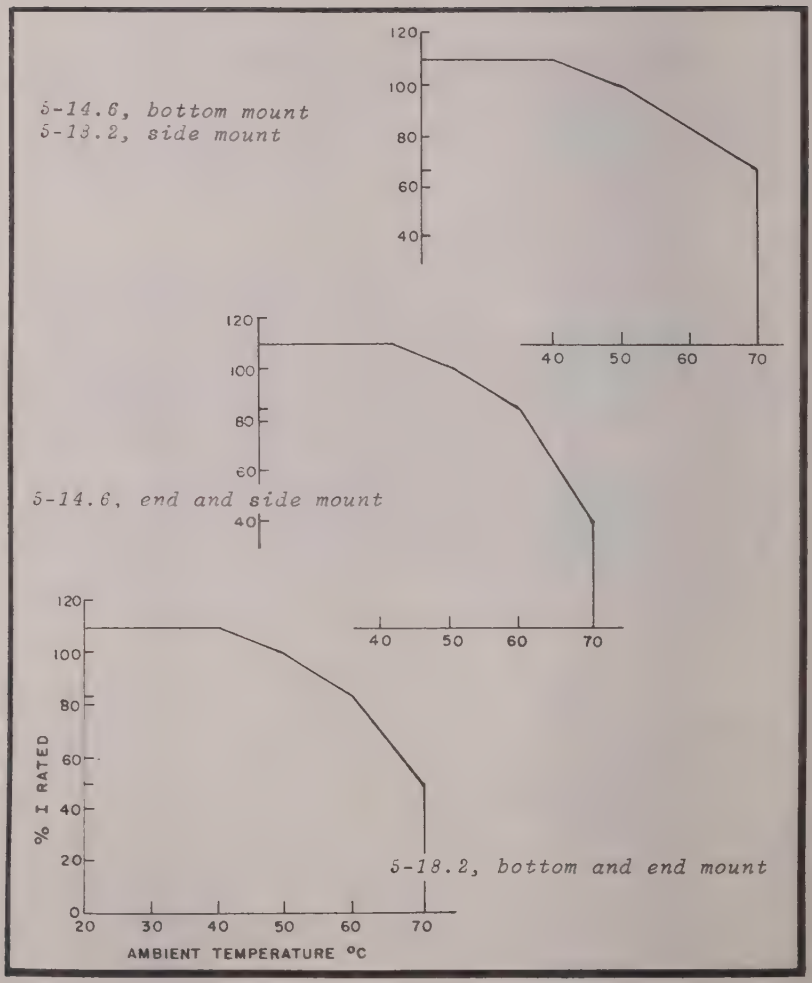


Figure 1-2. Current Derating

CHARACTERISTIC	MODEL	
	5-14.6	5-18.2
Input Ratings		
Voltage (Vac)	105-125/200-240/210-250	
Frequency (Hz)	50-480	
Phase	1	
Max. current (Aac)		
115 Vac input	3.4	4.6
230 Vac input	1.7	2.3
Power factor (typical)[1]	0.8	0.83
Efficiency (% - typical)[1]	36	36
Output ratings		
Voltage (Vdc)		
High-voltage range	4.5-6.5	
Low-voltage range	3-4.5	
Resolution (mV - typical)	22	
Current at 50°C (A)[2]		
High-voltage range	0-14.6	0-18.2
Low-voltage range	0-16	0-18.6
Current Foldback Characteristic	Figure 1-1	

1. At nominal input and full-rated output.
2. See Figure 1-2 for current derating characteristic.

Table 1-1 UNIT SPECIFICATIONS

CHARACTERISTIC	MODEL	
	5-14.6	5-18.2
Regulation (%)[3]	±0.01	
PARD (Ripple) 10Hz-7mHz Bandwidth		
RMS (uV) 50-60 Hz Input	300	
400 Hz Input	500	1000
Peak to Peak (3Hz-25mHz)		
50-60Hz Input (mV)	3	
400 Hz Input (mV)	10	15
Transient Response (us-typical)[4]	35	
Temperature Coefficient (%/°C - typical)	0.015	
Output Voltage Turn-on and Turn-off Overshoots	None	
Ambient Temperature (°C)	0-71	
Remote Programming		
Resistance	100 ±10 ohms/volt	
Voltage Signal	1 volt/volt	
Output Impedance (R + JwL)		
R (u ohms)	40	30
L (uH)	0.2	0.2

3. For combined load and line.
4. For a step-load change, no-load to full-load or full-load to no-load, and recovery to within a ±10mV band.

Table 1-1 UNIT SPECIFICATIONS (continued)

CHARACTERISTIC	MODEL	
	5-14.6	5-18.2
Stability[5]	0.025%/8 hours	
Series Operation	2 units	
Parallel Operation	master - slave	
Remote Sensing Compensation (max)	1.5 volts/load lead	
Cooling	Convection	
RFI characteristics (typical)	Meets Mil-I-6181 Mil-I-16910	
Envelope Dimensions (inches)		
Width	7-1/2	7-1/2
Height	3-15/16	4-15/16
Depth	9-1/2	9-3/8
Weight (pounds)	22	29

5. Eight hours after warm-up and with constant load, line, and ambient temperature.

Table 1-1 UNIT SPECIFICATIONS (continued)

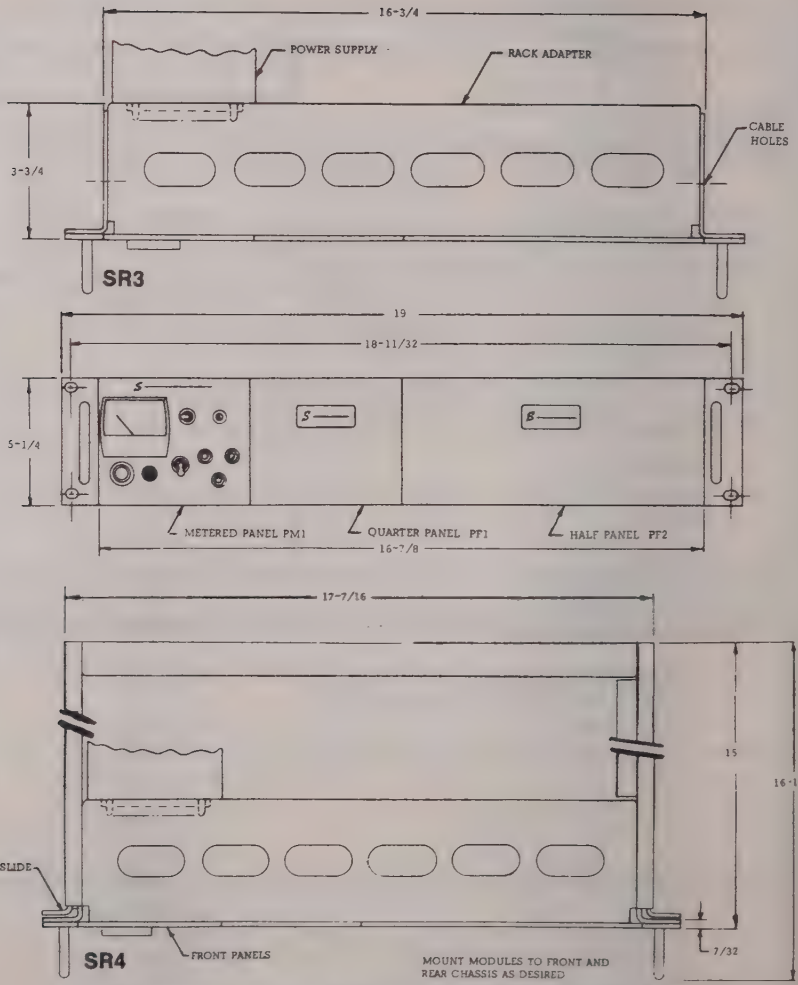


Figure 1-3. Rack Adapters SR-3 and SR-4

SECTION II

PREPARATION FOR USE

2-1 GENERAL.

2-2 After unpacking, an initial inspection and a preliminary checkout should be performed to assure that unit is in good working order. Basically, these consist of visually checking for damaged parts and components, and of making an electrical check. If it is determined that the unit is damaged, follow the instructions on the Damage and/or Loss in Shipment form enclosed with the unit, and notify the carrier immediately. The carrier's claim agent will then prepare a report of damage. The user is required to send this report to the Service Dept, Raytheon Company, Sorensen Operation, Norwalk, Connecticut 06856.

2-3 INSPECTION.

2-4 Check for damage incurred during shipment as follows:

a. Inspect enclosure for dents, chips, etc.

b. Check condition of external terminal board. Make certain that all screws are in place and that links are fitted over the barrier strips between the positive OUT terminal (1) and its adjacent SENSE terminal (2) and across the negative OUT terminal (4) and its adjacent SENSE terminal (3).

c. Using a slotted-drive screwdriver, rotate Output Adjust (adjust-access aperture located in nameplate) from stop-to-stop, and turn fully counterclockwise. Rotation should be smooth through a 300-degree angle.

d. Remove four screws retaining side enclosure plate, and inspect component board.

e. Remainder of enclosure may be removed by removing mounting screws and hex-head screws at nameplate

end. Inspect transformer, capacitors and passing-stage transistors.

Note

A guide pin, located at closed end of enclosure, should be used to align enclosure and chassis when reassembling unit. Tighten cap screws to 25 lb-in.

2-5 INPUT AND VOLTAGE RANGE CONNECTIONS.

2-6 The Dual Range models of the QSA supplies are normally factory wired for 115-volt AC operation, and high voltage output range (4.5V-6.5V). If operation from a 220 or 230 volt power source is desired, the taps on the primary of the power transformer, T1, may be rewired as shown in Figure 2-1. When low output voltage is required, the low voltage range (3V-4.5V) may be obtained by changing the taps on the transformer secondary, and adding a jumper across one of the bleeder resistors at the DC output. Schematic diagram, Figure 5-3, gives complete instructions for making the alterations.

Note

When changing the primary connections for 220V input, capacitor C4 remains connected between terminals #1 and #5. When the secondary is rewired for Low Output Range, capacitors C1 and C2 remain connected between terminals #16 and #18, and #16 and #14 respectively. Failure to observe these conditions will adversely affect the unit specifications.

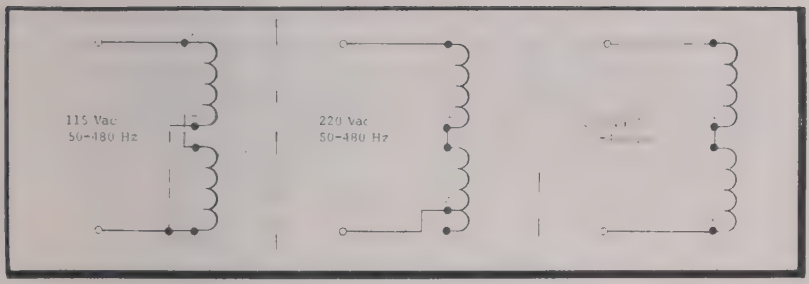


Figure 2-1. Input Connections

2-7 ELECTRICAL CHECK.

2-8 The initial electrical check is performed as follows:

a. Make sure that the unit is positioned so that a free flow of air is available.

b. Connect the primary input leads to terminals TB1-10/TB1-11 of the unit terminal board. Terminal TB1-9 may be used for an input system ground.

c. Connect a 10-volt dc voltmeter across terminals TB1-6 (+) and TB1-7.

d. Apply primary input power.

e. Rotate the Output Adjust control through its entire range. The voltmeter should vary over the range 4.5-6.5V (3V-4.5V if rewired for low-range operation).

f. Remove input power.

2-9 MOUNTING.

2-10 Versatile mounting arrangements are provided for the power supplies. They may be mounted on a chassis, panel, or in a rack cabinet. Tapped mounting holes are provided on the terminal panel end, the left side (viewed from the terminal panel side), and the bottom, of the enclosures. In all cases, a cutout must be made in the exterior mounting surface to provide a free flow of air to that side of the supply. Figure 2-2 shows the mounting-hole and minimum cut-out dimensions for end, side, or bottom mounting. Use 10-32 mounting screws, removing existing screws from the mounting holes as necessary. In

determining the length of the mounting screws, allow for washers and mounting surface thickness, and add 3/8 inch for maximum thread engagement in the mounting holes. Derate the maximum current shown in Figure 1-2, as necessary.

CAUTION

Knockouts are required for dissipation of the heat generated by the supplies. Do not reduce their dimensions, nor otherwise impede the natural flow of air around the supplies.

2-11 If units are to be rack-mounted in the optional SR3 adapter (see Figure 1-3) remove the adapter face plate, position the units behind the adapter, and attach them with the hardware supplied. Before replacing the face plate, check Section 3 and make any adjustments required for the particular application.

2-12 If units are to be rack-mounted in the optional SR4 adapter, remove the face plate (for front mounting only). Attach the units to the front or rear of the adapter, as desired, using the hardware supplied. Before replacing the face plate or otherwise making the assembly inaccessible, check Section 3 and make any adjustments required for the particular application.

2-13 If the optional meter panel is to be used, the correct method of wiring is shown in Figure 2-3.

MODEL	A	B	C	D	E
5-14.6	7 7/8	7 3/8	7 7/8	8 1/8	3/8
5-18.2	10 15/64	9 5/8	9 35/64	9 5/8	13/32

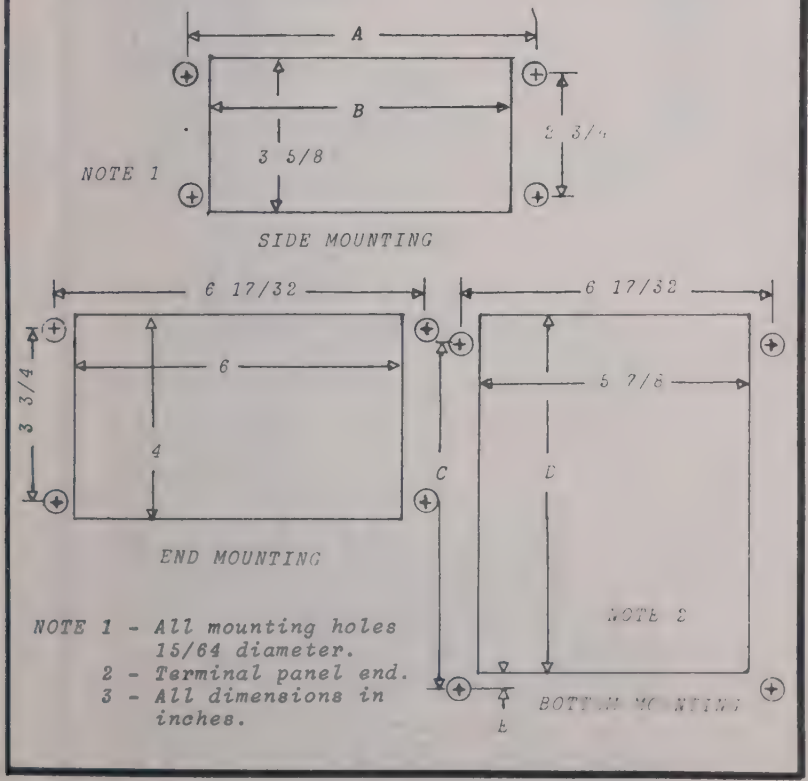


Figure 2-2. Mounting Hole and Cutout Dimensions

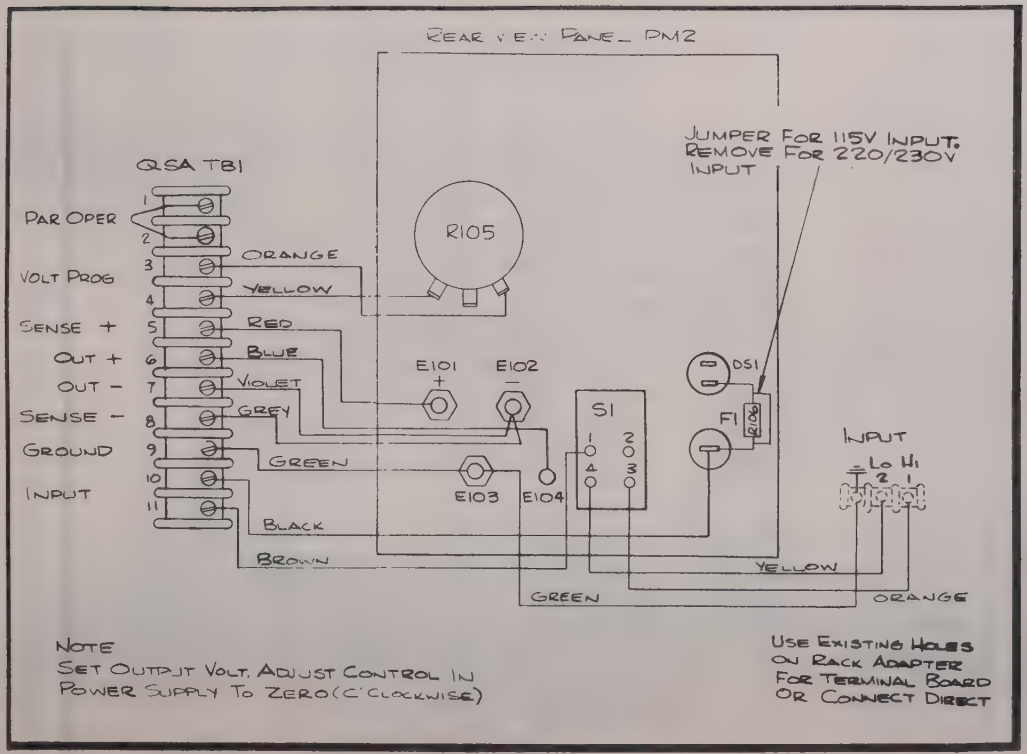


Figure 2-3. Rack Adapter Panels, Meter Wiring

SECTION III

OPERATING INSTRUCTIONS

3-1 GENERAL.

3-2 This Section contains instructions for adapting these power supplies to, and operating them in, a number of applications. These include remote sensing, remote programming, and series and parallel operation.

CAUTION

The sensing and power circuits in these supplies form a closed loop. Opening this loop by removing a terminal-board link or disconnecting a sensing or programming lead will result in high unit output and may damage the supply or load.

3-3 CONTROLS.

3-4 The Models 5-14.6 and 5-18.2 power supplies each have three screwdriver-adjustable controls, accessible through holes in the terminal panel end of the power-supply enclosures. The names, functions, and location of these controls are:

a. OUTPUT ADJ control (R18) - sets output voltage at any point within range and resolution of supply - top center of panel.

b. Short Circuit Adjust control (R31) - sets output current flow with short-circuit across output terminals - just above and to left of fuse post.

c. Foldback Adjust control - (R5) - sets value

at which output current begins to decrease with increasing load - directly below R31 access hole.

3-5 ROUTINE OPERATION.

3-6 The Models 5-14.6 and 5-18.2 power supplies are ready to operate as they are shipped from the factory, and are normally connected and adjusted for local sensing, local control of voltage, and operation on the high-voltage range. All that need be done is to make the input and output connections and adjust the output voltage to the desired value. However, a number of modifications of the factory connections and adjustments are possible. Two of these, altering the input connections to correspond to the primary voltage available, and changing the output voltage range, have already been discussed in Section 2 and must be made, if needed, before applying primary power. In addition, a number of modifications of adjustments and connections are discussed in the following paragraphs of this Section. Some of these are optional, some are mandatory, for example, the derating and readjustment of the supplies for operation in temperatures above 50°C. The user should consider all these modifications and determine if any are necessary or applicable to his conditions. The supply is connected and placed in operation as follows:

a. Connect the primary input wires to terminals TB1-10/TB1-11 on the unit terminal panel.

b. If a primary system ground is desired, connect this to terminal TB1-9.

c. Connect a voltmeter across terminals TB1-6 and TB1-7. Apply primary power and adjust the output voltage to the value wanted with the OUTPUT ADJ control.

CAUTION

If the supply has been modified for remote sensing (discussed later), make sure that terminal TB1-5 is

connected through the load and sensing leads to terminal TB1-6 and that TB1-7 is similarly connected to TB1-8. If not, an excessive and uncontrollable output voltage will result.

d. Remove the primary power and connect the load across terminals TB1-6 (+) and TB1-7. The supply is now ready for operation.

WARNING

Never touch the power supplies while they are operating under load, nor for some time thereafter. Since the enclosures are used as heat sinks, their surface temperature tends to be high. If a unit must be handled immediately after operation, wear heat-resisting gloves.

3-7 CURRENT/TEMPERATURE COMPENSATION.

3-8 Both models of power supply are protected from overload - including complete short-circuit - by internal circuitry which functions automatically. When the load tends to draw more than a safe amount of current, the output voltage and current decrease in proportion to the amount of overload (current foldback). At short-circuit, the output voltage drops to zero and the current assumes a minimum safe value. The point at which the current begins to decrease with increasing load, and the current value at short-circuit, are both adjustable. At the factory, the start of current foldback is set at 107% of normal maximum operating current at 50°C: the short-circuit current is set at 52%. With these adjustments, the supplies may be operated at any ambient temperature between 0°C and 50°C. If a supply is to operate in an ambient temperature higher than 50°C, the foldback and short-circuit currents must be reset for proper protection . The new currents are circulated, and the controls are then adjusted.

3-9 Compensation Calculation. To calculate the foldback and short-circuit currents:

a. Measure the temperature of the environment in which the unit will operate. Find this temperature along the horizontal axis of the appropriate drawing, Figure 1-2.

b. Extend a vertical line upward until it intersects the curve. Extend a horizontal line from the intersection to the left until it meets the vertical axis. The intersection here is the percentage of derating.

c. Multiply this percentage (expressed as a decimal) by the output current at 50°C (Table 1-1). The figure obtained is the new, maximum operating current at the higher ambient temperature.

d. The current foldback point is taken as a percentage of the derated maximum operating current. An arbitrarily safe percentage figure may be used, or a percentage may be used which takes into account the temperature sensitivity of the current-foldback circuit. Both methods are described in the following subparagraphs.

(1) Multiply the new operating current maximum by 1.1. The result is the new foldback current value, without regard to the temperature characteristics of the foldback circuit.

(2) Alternatively, multiply the new operating current maximum by X% (expressed as a decimal), where:

$$X = 107 + \Delta T(0.06)$$

ΔT being defined as:

$$\Delta T = 40 - (\text{actual ambient in } °C)$$

The result is the new foldback current value, with the foldback circuit temperature characteristics taken into account.

e. Compute the new short-circuit value as 52% of the new maximum operating current.

3-10 Sample Calculation. Assume a bottom-mounted Model 5-14.6 is to be operated in an ambient temperature of 61°C on its high-voltage range:

a. Derating percentage = 80% (Figure 1-2)

b. Maximum operating current at 50°C = 14.6A (Table 1-1).

c. 0.80 x 14.6 = 11.7A (maximum operating current at 61°C).

d. 11.7 x 1.1 = 13 (new current-foldback setting)

e. 11.7 x 0.52 = 6.1 (new short-circuit current setting).

3-11 FOLDBACK AND SHORT-CIRCUIT CURRENT ADJUSTMENT.

3-12 To adjust the foldback and short-circuit current controls:

a. Rotate the Foldback Adjust potentiometer R5 and the Short-circuit Adjust potentiometer R31 fully counter-clockwise.

b. Connect a voltmeter across the output terminals of the supply. Apply nominal input voltage and adjust the output voltage to the lower limit of the unit's range (4.5V on the high-voltage range, 3.0V on the low-voltage range). If the supply is to be used at a fixed voltage above the lower limit, set the output voltage to the fixed value.

c. Remove the input power and connect an ammeter (+ 0.5%) and a variable load resistor in series across the output terminals.

d. Reapply the input power and adjust the load until the ammeter reads the calculated value of foldback current.

e. Adjust R5 until the current just begins to drop.

f. Place a jumper across the load resistor. adjust R31 until the ammeter reads the calculated value of short-circuit current. Remove the jumper from the load.

g. Repeat steps d-e-f until the specified currents are obtained with no further adjustment of R31 or R5.

h. Make a final check by increasing the load resistance until the current drops appreciably below the foldback value. Then decrease the load resistance slowly to zero. The current should rise to the foldback value, then drop to the short-circuit value as the load resistance decreases progressively to zero.

3-13 REMOTE SENSING.

3-14 As shipped, these power supplies are connected to sense (regulate) the voltage appearing at their terminal panel connections. If it is desirable to sense (regulate) unit output at the load rather than at output terminals, the remote sense feature must be used. This arrangement will compensate for up to 1.5 volts drop in each load lead. To use this feature:

a. Remove the links between the terminal pairs TB1-5/TB1-6 and TB1-7/TB1-8.

b. Connect the power supply to the load as shown in Figure 3-1. Use coaxial cable for the sensing leads at TB1-5/TB1-8, connecting the shield of the cable to TB1-8.

c. Place the unit in operation as described in paragraph 3-5.

Note

The transient response of the power supply will degenerate slightly when using remote sensing. If this is undesirable, remove the output capacitor C7 (see schematic diagram) and reconnect it directly across the load terminals. An electrically identical capacitor may be used, if desired - see Parts List.

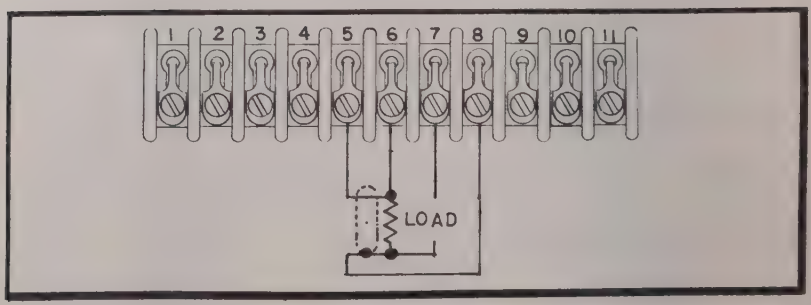


Figure 3-1. Remote Sensing

3-15 REMOTE PROGRAMMING.

3-16 The factory-shipped unit is connected for local control of output voltage by varying the setting of the OUTPUT ADJ control. If it is desired to control the output voltage from a remote point, this may be done by either a remote resistance control or by supplying a voltage signal from the remote point. Both methods are described in the following subparagraphs.

3-17 RESISTANCE PROGRAMMING. The value of the programming resistance must be 100 ohms, ±10 ohms, for each volt of output required. Thus, for 4.5 volts output, a resistance of approximately 450 ohms is needed. The resistor must have a temperature coefficient of not greater than 30ppm/°C and must carry the programming current of load. Its wattage rating must be at least 10 times the calculated dissipation. Alter the power-supply connections in the following manner:

CAUTION

The programming resistance value must not be larger, in terms of 100 ohms/volt, than the maximum voltage rating of the supply. A larger resistor will force the supply to operate outside its ratings, with possible damage and loss of regulation.

a. Turn the OUTPUT ADJ control fully counterclockwise, since the control will not be used in this application.

b. Remove the link between terminal pair TB1-3 and TB1-4. Connect the programming resistor across these terminals. Use twisted-pair or shielded wire between the resistor and the terminal board - if shielded wire is used ground the shield at TB1-9 (see Figure 3-2).

c. With no load, apply primary power and measure the output voltage to verify that it is the desired value.

d. Shut off the primary power and place the unit in operation as described in paragraph 3-5.

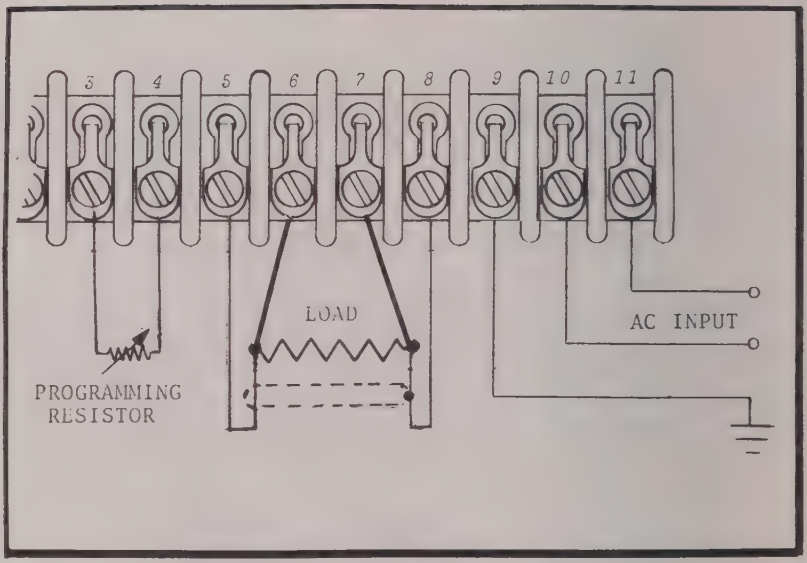


Figure 3-2. Remote Programming

3-18 VOLTAGE PROGRAMMING. The value of the voltage-programming signal must be 1 volt for each volt of power-supply output, but never greater than the maximum voltage rating of the supply (see the CAUTION under Resistance Programming). The signal source must be floating (ungrounded) and capable of absorbing the 10mA programming current. Noise and ripple on the signal will tend to appear in the power supply output.

3-19 The alteration of the power-supply connections is identical to that for resistance programming, except the signal source is connected across TB1-3/TB1-4 instead of the programming resistor.

3-20 SERIES OPERATION.

3-21 Two units may be connected in series to give up to twice the output voltage of one unit. Maximum current

output will be the same as for one unit. Voltage regulation will be the sum of the individual voltage regulations.

3-22 If a series-connected unit fails, a reverse-polarity voltage will appear across its output terminals, with possible damage to the output capacitor. To prevent this, the reverse voltage must be clamped to about 1 volt by connecting an external rectifier across the output terminals of each supply. Table 3-1 lists the recommended rectifiers for this use.

QSA MODEL	MANUFACTURER	MFR PART NO.	SORENSEN PART NO.
5-14.6	Westinghouse	409A	26-1096-1
5-18.2	Westinghouse	417A	26-1096-1

Table 3-1. Rectifier Recommendations, Series Operation

3-23 To connect two units in series, see Figure 3-3, and:

a. Remove the link between terminal pair TB1-7 and TB1-8 on one unit. For convenience call this Unit 1.

b. Connect a lead from TB1-6 of Unit 1 to the positive side of the load.

c. Connect a lead from TB1-7 of Unit 2 to the negative side of the load.

d. Connect TB1-7 of Unit 1 to TB1-6 of Unit 2.

e. Run a sensing lead from TB1-8 of Unit 1 to TB1-6 of Unit 2.

f. If local sensing is to be used, skip this step. For remote sensing, remove the links between terminal pairs TB1-5/TB1-6 of Unit 1 and TB1-7/TB1-8 of Unit 2. Run sensing leads from TB1-5 of Unit 1 and TB1-8 of Unit 2 directly to the load, as shown.

g. Place the units in operation as described in paragraph 3-5.

3-24 PARALLEL OPERATION.

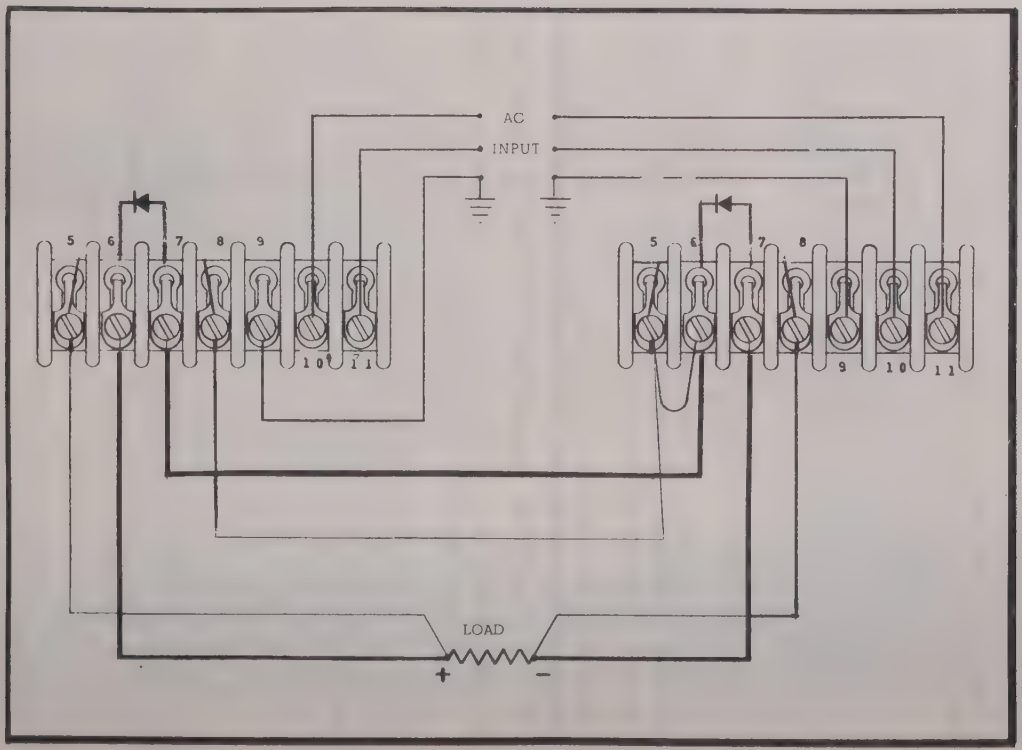


Figure 3-3. Series Operation

3-25 Loads which draw currents higher than a single unit's rated output may be serviced by paralleling units. Parallel operation is based on the "master-slave" concept, i.e., the "master" unit amplifier supplies drive current to all "slave" units. ("Slave unit amplifiers are disconnected during the paralleling procedure.)

3-26 The number of units which may be paralleled using the "master-slave" approach is dependent upon the amount of current available to drive the "slave" unit passing stages. This current is a variable from unit-to-unit, and depends upon dissimilarities, within acceptable tolerances, in component characteristics. The maximum number of units which may be paralleled is therefore a function of the "master" unit selected and may vary anywhere from 4, in the worst case, to 15.

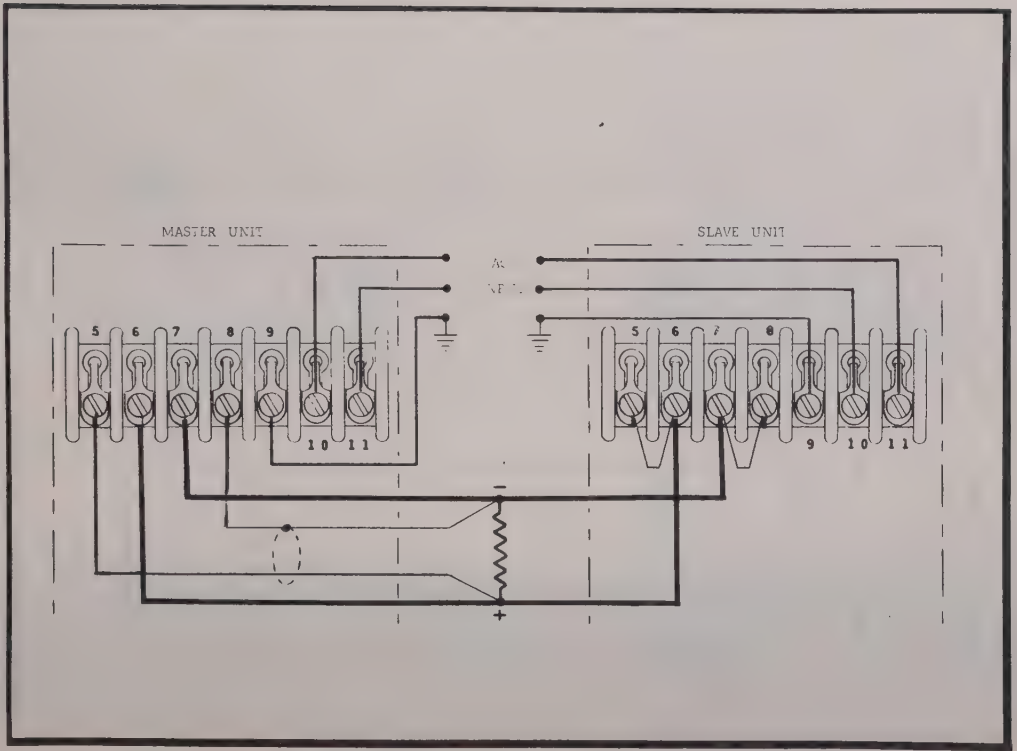


Figure 3-4. Parallel Operation

SECTION IV

PRINCIPLES OF OPERATION

4-1 GENERAL.

4-2 This section contains a description of the operating principles of the Models 5-14.6 and 5-18.2 power supplies, first in broad terms and then in more detail. Its function is to provide sufficient data which, when used in conjunction with the maintenance data and procedures outlined in Section V, will enable the user to logically and quickly isolate any malfunction.

4-3 PASSING-STAGE PRINCIPLE.

4-4 The supplies utilize the series-passing-stage method of regulation. With this approach, a variable impedance absorbs the difference between the desired regulated output and filtered "brute-force" d-c. The variable impedance, to simplify this discussion, is assumed to be a single transistor (actually, a number are connected in parallel in both supplies). Automatic regulation occurs when an output-derived error signal, fed back through amplifiers, is applied to the transistor, or passing stage, base. Figure 4-1 is an idealization, using input and output waveforms, of passing-stage operation.

4-5 BLOCK DIAGRAM.

4-6 The following brief description discusses unit operating principles in a general manner. A more detailed treatment is presented in subsequent paragraphs. Refer to Figure 4-2: the input transformer accepts an a-c input, steps down the voltage and applies it across a full-wave, center-tapped rectifier. Rectifier output

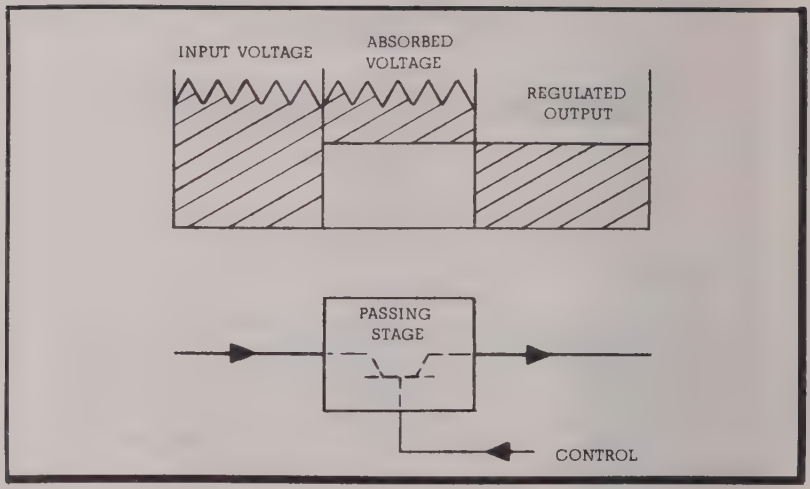


Figure 4-1. Series Passing Stage Principle

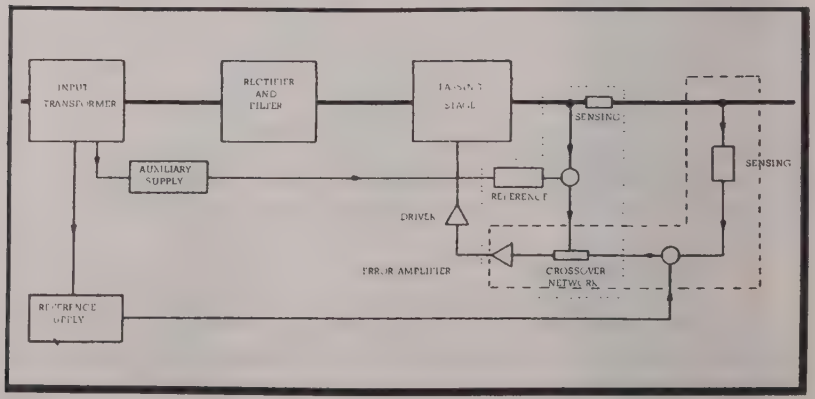


Figure 4-2. Block Diagram

is fed through a passing stage to the load. The passing stage acts to absorb the difference between the rectifier and desired voltage. The feedback loop to the passing stage includes a sensing network which compares a sample of the unit's output against a fixed reference, provided by an internal reference power supply. Error signals resulting from the comparison are diffentially amplified and fed to the drivers. These signals are used to alter the impedance of the passing stage as a function of unit output. Short-circuit and overload protection is provided by a current-foldback section.

4-7 DETAILED DISCUSSION.

4-8 REFERENCE POWER SUPPLY. The reference power supply provides 9 volts of highly stable, precise direct current as a reference for the sensing and error-amplification section. The supply derives its power from a full-wave, center-tapped rectifier, CR6 and CR7, connected across a secondary winding T1. Basic supply components include transistor Q5, two differential amplifiers Q6-Q7, Q8-Q9, and zener diode CR8.

Note

For schematic locations of reference designations used throughout this section, see Figure 5-3.

4-9 Reference-supply output is sensed across resistors R28 and R15 where the drop across R28 is compared with a voltage reference developed by diode CR8. Resulting error signals are amplified and directed to the base of transistor Q5. Q5 acts as a variable impedance, increasing or decreasing the voltage drop across the stage as a function of the output voltage.

4-10 As an illustration of circuit operation, assume that an increase in reference-supply output voltage is sensed across resistor R28. A portion of the sensed voltage is compared with the constant voltage developed

across CR8. The resulting error signal forces Q9 into higher conduction. The current through Q9 increases, while that through Q8 decreases. Resistor R16 acts as a current generator, pulling an approximately constant current that is the sum of the operating currents of Q8 and Q9. Increasing current through Q9 brings about a decrease in drive current on the base of Q6. Operating current through Q6 drops, decreasing the drive to Q5. As a result, Q5 conducts less (impedance increases) and the voltage across R15 is regulated to the precise 9-volt output.

4-11 SENSING AND ERROR-AMPLIFIER SECTION. In this section, a comparison is made between the precise output from the previously described reference supply and a portion of the unit output voltage. Resulting error signals are differentially amplified and fed to the passing-stage section. Main components include output-adjust potentiometer R18, resistor R25, and differential amplifiers Q12-Q13 and Q10-Q11.

4-12 As an illustrative example of circuit operation, assume that the output voltage starts to rise. The voltage across R18 increases and therefore the base of Q12 becomes more negative with respect to the base of Q13. The operating current through Q12 decreases, and the current in Q13 increases. The increase results because the sum of the operating currents of Q12 and Q13 is held approximately constant by R24. With a decrease of current through Q12, there is a decrease in drive on the base of Q10 and an increase in base Q11 drive current. Q10 therefore will go into a state of lower conduction, reducing the drive on Q4 and subsequently increasing the impedance of passing stage Q2 via Q4-Q3.

4-13 DRIVERS AND PASSING STAGE. The drivers and passing stage are composed basically of two amplifiers (drivers) Q4-Q3, and transistor Q2 connected in the positive output leg. Driver Q4 amplifies the signal from Q10 and feeds it to the base of Q3. The signal is again amplified in Q3 and directed to the base of Q2 where it determines Q2's conduction level, causing an increase or decrease in the absorbed voltage as a function of unit output.

4-14 CURRENT-FOLDBACK SECTION. This portion of the power-supply circuitry provides overload and short-circuit protection. When the power supply is overloaded, transistors Q14-Q16 not only prevent the output current from rising beyond a safe maximum, but actually cause the current to decrease (fold back). With a short-circuit load, the current is reduced to a safe minimum (but not zero).

4-15 Under normal operating conditions, Q16 is saturated and serves simply as a closed switch for emitter-current flow to Q10-Q11. At the same time, transistor Q15 is saturated and transistor Q14 is near cut-off. The biasing conditions which set the operating points of Q14-Q15 are determined by the voltage drop across diode CR13 and the settings of Foldback Adjust potentiometer R5 and Short-circuit Adjust potentiometer R31. Increasing load-current flow through resistor R7A tends to move the base of Q15 in the negative direction with respect to its emitter, but up to the current-foldback point (determined by the setting of R5) Q15 remains saturated and no further action takes place in the foldback circuit. Beyond the foldback point, the increasingly negative base of Q15 causes current flow through that transistor to diminish, and its collector and the base of Q16 move in the positive direction. Current flow through A10-A11 to the drivers Q3-Q4/Q17 and the pass stage Q2 is accordingly reduced, increasing the impedance of Q2 and reducing the load current. At short-circuit load, the load current is reduced to a minimum determined by the setting of Short-circuit Adjust potentiometer R31.

4-16 SUPPLEMENTARY VOLTAGE SOURCES.

4-17 Two supplementary sources provide internal power for various uses. The rectifier-filter combination CR11-CR12/C18 supplies voltage to the collectors of driver stages Q3-Q4. Rectifier-filter CR9-C19 furnishes biasing voltages in the current-foldback circuit and collector current Q10.

SECTION V

MAINTENANCE

5-1 GENERAL.

5-2 This section provides troubleshooting data and calibration and performance-testing procedures. The troubleshooting data should be used in conjunction with the schematic diagram (Figure 5-3), which tabulates voltage-check points, with Section IV-which outlines the principles of operation, and with Figures 5-1 and 5-2 which physically locate the parts appearing on the schematic. Any questions pertaining to repair should be directed to the nearest Sorensen representative (a list is included with the unit) or to the Service Department, Raytheon Company, Sorensen Operation, Norwalk, Connecticut 06856. Include the model and serial numbers in any correspondence. Should it be necessary to return a unit to the factory for repair, authorization from the Sorensen Service Department must be obtained first. Raytheon Company will not assume responsibility for units returned without prior authorization.

5-3 PERIODIC SERVICING.

5-4 The power supplies require no periodic servicing. However, whenever a unit is taken off the line, the enclosure should be inspected and cleaned of any accumulations of dust or other debris which could impede natural air flow through the unit.

5-5 TROUBLESHOOTING.

5-6 Table 5-1 lists a number of malfunction symptons and their probable causes. The table covers symptoms which are attributed to a single component failure only. This should not be interpreted to mean that there could

not be other causes for the tabulated symptoms. Multiple failures, for instance, may give identical indications. Footnotes in the table indicate which components may be damaged due to a "chain-reaction" effect. If any amplifier components are replaced, unit may require a calibration check (para. 5-7) or a performance test (para. 5-9).

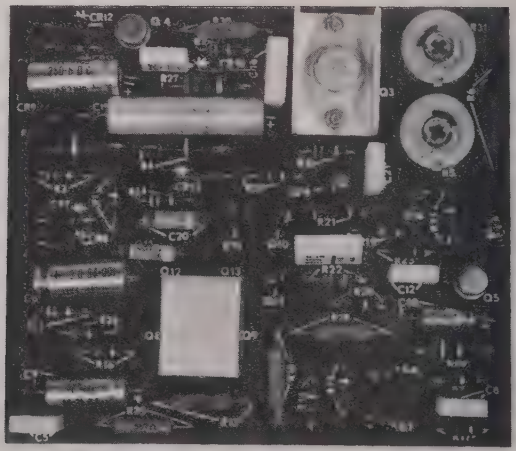


Figure 5-1. Typical Component Board

5-7 CALIBRATION CHECK.

5-8 The Models 5-14.6 and 5-18.2 power supplies require no calibration, in the sense that they have no internal, semi-permanent control settings which affect their performance. If the user wishes to check the general range of performance - perhaps following replacement of a defective part, a voltmeter, ammeter, and variable load resistance may be connected across the output terminals. Apply nominal line voltage and rotate the OUTPUT ADJ control through its limits to determine that the output voltage varies over the specified range. Vary the load resis-

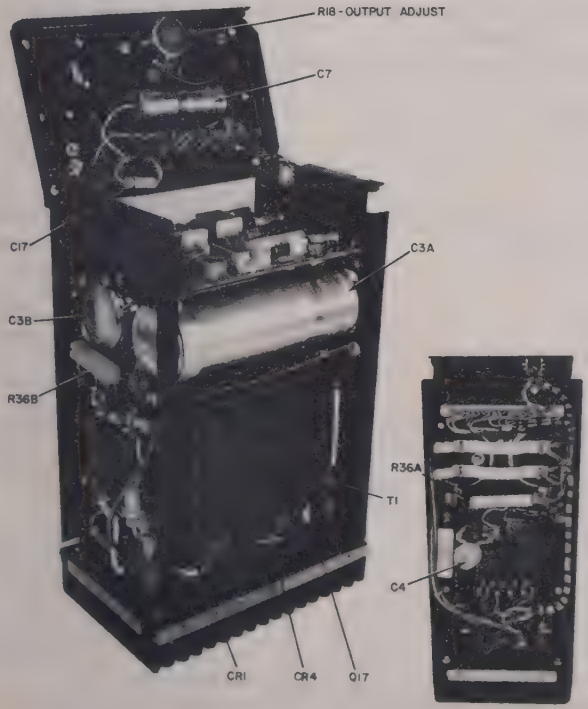


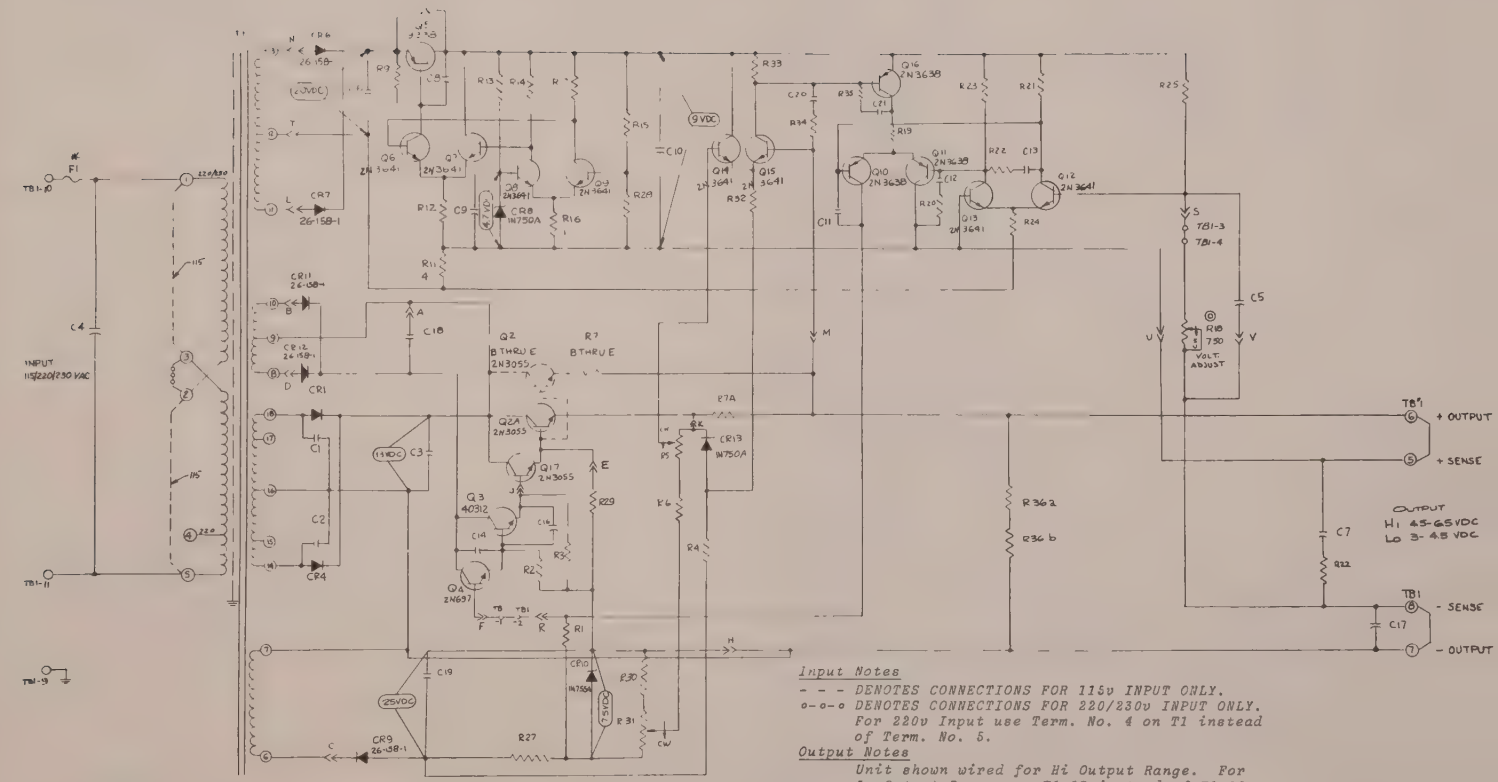
Figure 5-2. Partial Disassembly

tance to determine the normal current range, and observe the current values at foldback and short-circuit. Voltage and current data will be found in Table 1-1, and adjustment procedures in Section 3.

SYMPTOM	PROBABLE CAUSE
No Output	a. No input b. Fuse blown (check for shorted rectifier CR1, CR4, CR6-CR7[1],or shorted transformer winding).
High Output	a. In reference supply, Q9, Q7, or CR8 open. Q8, Q6, or Q5 shorted, b. Q2-Q4/Q17 shorted[2]. c. In sensing and error-amplification section, Q10 or Q13 shorted, or Q11 or Q12 open.
Low or Negative Output	a. In reference supply, Q9, Q7 or CR8 shorted. Q8, Q6 or Q5 open. b. Q3-Q4 open. c. In sensing and error-amplification section, Q10 or Q13 open, or Q11 or Q12 shorted. d. In current-foldback section, Q15, Q16 open, defective R5.
Output Ripple Degenerates	CR1 or CR4 open.

1 Complementary rectifier and transformer may be damaged.
2 When replacing Q2, apply silicon oil to underside of transistor.

Table 5-1. Troubleshooting Data



NOTES

1. *Denotes panel control.*
2. *All voltages measured at Nominal Input, Nominal Output, No Load.*

Input Notes

- - - DENOTES CONNECTIONS FOR 115v INPUT ONLY.
o-o-o DENOTES CONNECTIONS FOR 220/230v INPUT ONLY. For 220v Input use Term. No. 4 on T1 instead of Term. No. 5.

Output Notes

Unit shown wired for Hi Output Range. For Lo Output Range use T1-17 instead of T1-18 and T1-15 instead of T1-14 and connect a jumper wire across R36b.

Figure 5-3. Schematic Diagram

tance to determine the nominal current range, and observe the current values at foldback and short-circuit. Voltage and current data will be found in Table 1-1, and adjustment procedures in Section 3.

5-9 PERFORMANCE TESTING.

5-10 OUTPUT RIPPLE. To measure output ripple, proceed as follows:

a. Connect a test set-up as shown in Figure 5-4. Set oscilloscope for 1.0mV/cm vertical and 10ms/cm horizontal. (Oscilloscope should have at least a 30 MHz band width.) Select a 150V range for a-c voltmeter. Choose

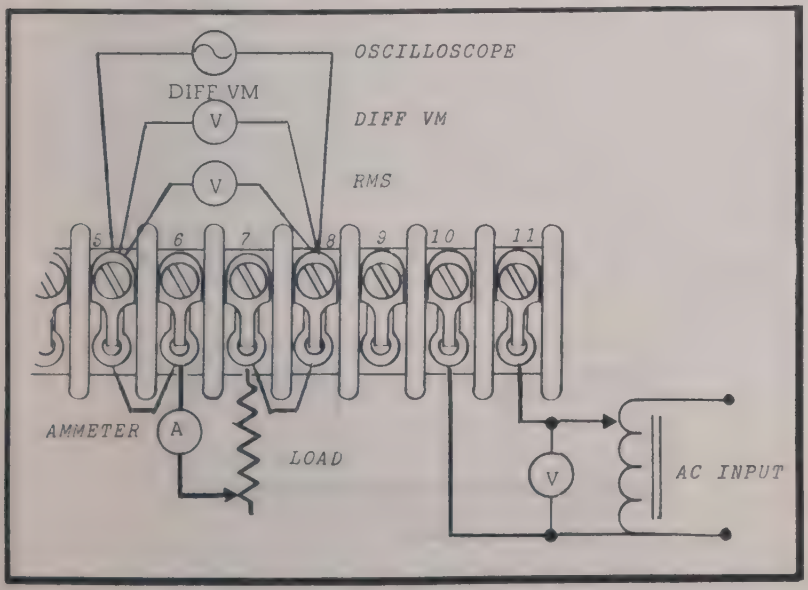


Figure 5-4. Performance Test Setup

a 1.0mV range for RMS meter and a 25A range for d-c ammeter. Use a resistive load with a current-drawing capacity of at least 25A. Use the differential voltmeter as a VTVM. Select a 10V range.

b. With no load, apply a 115 Vac, 60 Hz input, and adjust output to 6V dc (if supply is on high-voltage range) or 3.5V (low-voltage range).

c. Apply full load and observe the RMS and peak ripple on the RMS voltmeter and oscilloscope, respectively. These values should be no greater than given in Table 1-1.

d. If desired, check regulation per para. 5-11.

5-11 REGULATION. To measure unit's output regulation, proceed as follows:

a. Connect unit to test set-up shown in Figure 5-4. The oscilloscope and RMS voltmeter are not necessary. Use the differential voltmeter in the differential mode. Select an internal voltage equal to 6V d-c (if supply is on high-voltage range) or 3.5V (low-voltage range), and set null sensitivity to the 10mV range.

b. Apply a 115 Vac, 60 Hz input, and adjust output voltage to obtain a null indication on voltmeter with no load.

c. With a-c voltmeter indicating 115 Vac, increase load on unit until d-c ammeter reads as shown in Table 5-2. Record the deviation from voltmeter null position.

RANGE	Hi - V	Lo - V
5-14.6	16.1A	17.6A
5-18.2	20A	20.5A

Table 5-2. Currents For Regulation Test.

d. Adjust voltmeter internal voltage to regain the null position. Then, with full load on unit, vary

unit input voltage at 60 Hz from 105 to 125 Vac. Note the deviation.

e. Sum the deviations recorded in steps c and d. The total should not be greater than 1.2mV (high-voltage range) or 0.7mV (low-voltage range).

SECTION VI

REPLACEMENT PARTS LIST

6-1 GENERAL.

6-2 This section provides a replacement parts list for QSA Models 5-14.6 and 5-18.2. The list is keyed to the schematic diagram.

6-3 MANUFACTURER CODING.

6-4 The column headed MANUFACTURER CODE contains a listing of letter designators which, when applied to the tabulation that follows, will give the manufacturer from whom a particular item may be purchased. If no manufacturer's part number is listed in the MANUFACTURER PART NO. column, the part may be ordered from the indicated manufacturer by using the Sorensen part number and a complete description of the item.

AB	Allen Bradley Company
AX	Aerovox Corporation
CB	Centralab, Div. of Globe Union, Inc.
CS	Clarostat Manufacturing Co., Inc.
CTS	CTS Inc.
FC	Fairchild Semiconductor
GE	General Electric Co.
IRC	International Resistance Co.
LF	Littlefuse Company
MA	Motorola Semiconductor Products
RCA	Radio Corporation of America
RDM	Radio Material Co., Div. P.R. Mallory
RS	Raytheon Co., Sorensen Operation
RT	Raytheon Company

SA	Sangamo Electric Company
SE	Seacor Inc.
SC	Semicon, Inc.
SP	Sprague Electric Company
WH	Westinghouse Electric Corp.
WL	Ward Leonard Electric Company

6-5 ORDERING PARTS.

6-6 When ordering parts from Raytheon Company, Sorensen Operation, include manufacturer's part number, the Sorensen part number and the unit model number. Address orders to:

Raytheon Company
Sorensen Operation
Norwalk, Conn. 06856

REF DES	MODEL 5-14.6	MODEL 5-18.2	DESCRIPTION	SORENSEN PART NO.	MANUFACTURER PART NO.	MANUFACTURER CODE
C1,2	X		Cap., 50 nF, 500V	24-2010		CB
		X	Cap., 10 nF, 500V	24-2409-13		AX
C3	2	2	Cap., 32 mF, 15V	24-2454-7		SP
C4	X	X	Cap., 20 nF, 900Vac	24-026		RDM
C5,8, 14	X	X	Cap., 10 nF, 250V	24-2015-1		SE
C6	X	X	Cap., 100 µF, 25V	24-2279-14		SP
C7	X	X	Cap., 3.5 mF, 15V	24-2441-5		SP
C9	X	X	Cap., 50 µF, 25V	24-2279-12		SP
C10	X	X	Cap., 4 µF, 25V	24-2279-4		SP
C11	X	X	Cap., 4.7 nF, 200V	24-2409-5		AX
C12	X	X	Cap., 33 nF, 250V	24-2015-7		SE
C13	X	X	Cap., 150 nF, 250V	24-2015-15		SE
C15			NOT USED			
C16,17	X	X	Cap., 100 nF, 250V	24-2015-13		SE
C18	X	X	Cap., 250 µF, 6V	24-2275-18		SP
C19	X	X	Cap., 110 µF, 30V	24-2567		SA
C20	X	X	Cap., 1.5 nF, 200V	24-2409-2		AX
C21	X	X	Cap., 22 nF, 250V	24-2015-5		SE
CR1,4	X		Rectifier	26-1094-1		WH
		X	Rectifier	26-1095-1		WH
CR2,3,5 CR6,7,9 11,12	X	X	NOT USED Rectifier	26-158-1		SC
CR8,13	X	X	Zener Diode	26-211	IN750A	MA
CR10	X	X	Zener Diode	26-262	IN755A	MA

Table 6-1. Replacement Parts List (Sheet 1 of 3)

REF DES	MODEL 5-14.6	MODEL 5-18.2	DESCRIPTION	SORENSEN PART NO.	MANUFACTURER PART NO.	MANUFACTURER CODE
F1	X		Fuse, 4A, 250V	42-847		LF
		X	Fuse, 5A, 250V	42-413		LF
Q2	4	5	Transistor, NPN	18-151		RCA
Q3	X	X	Transistor, NPN	18-142		RCA
Q4	X	X	Transistor, NPN	18-115	2N697	GE
Q5	X	X	Transistor, PNP	18-146	RT 9338	RT
Q6-9 12-15	X	X	Transistor, NPN	18-144		FC
Q10,11, 16	X	X	Transistor, PNP	18-143		FC
Q17	X	X	Transistor, NPN	18-151		RCA
R1	X	X	Res,10k ohm,1/2W	27-133	EB 1031	AB
R2,24	X	X	Res,680 ohm,1/2W	27-156	EB 6811	AB
R3,35	X	X	Res,330 ohm,1/2W	27-102	EB 3311	AB
R4	X	X	Res,1.5k ohm,1W	27-295	GB 1521	AB
R5,31	X	X	Pot,5k ohm,±20%,2W	29-544		CTS
R6	X	X	Pot,15kohm,±1%,1/2W	28-1260		IRC
R7	4	5	Res,0.27ohm,±5%,7W	27-1524		WL
R9,19	X	X	Res,220 ohm,1/2W	27-101	EB 2211	AB
R10	X	X	Res,390 ohm,1W	28-703	GB 3911	AB
R11,34	X	X	Res,47 ohm,1/2W	27-181	EB 4701	AB
R12	X	X	Res,820 ohm,1/2W	27-182	EB 8211	AB

Note: Resistor tolerance is ±10% unless otherwise specified

Table 6-1. Replacement Parts List (Sheet 2 of 3)

REF DES	MODEL 5-14.6	MODEL 5-18.2	DESCRIPTION	SORENSEN PART NO.	MANUFACTURER PART NO.	MANUFACTURER CODE
R13	X	X	Res,221ohm,±1%,1/2W	28-1188		IRC
R14,16, 17	X	X	Res,1.8k ohm, 1/2W	27-176	EB 1821	AB
R15,25	X	X	Res,887ohm,±1%,1/2W	28-1216		IRC
R18	X	X	Pot, 750 ohm, 4W	29-545		CS
R20	X	X	Res, 82 ohm, 1/2W	27-1115	EB 8201	AB
R21,23	X	X	Res,1.5k ohm, 1/2W	27-171	EB 1521	AB
R22	X	X	Res, 68 ohm, 1/2W	27-160	EB 6801	AB
R27	X	X	Res, 680 ohm, 1W	28-701	GB 6811	AB
R28	X	X	Res,953ohm,±1%,1/2W	28-1234		IRC
R29	X	X	Res, 100 ohm, 2W	27-356	HB 1011	AB
R30	X	X	Res,475ohm,±1%,1/2W	28-1146		IRC
R32	X	X	Res, 2.7k ohm, 1/2W	27-174	EB 2721	AB
R33	X	X	Res, 1.2k ohm, 1/2W	27-1110	EB 1221	AB
R36a,b	X	X	Res, 5 ohm, 10W	27-599-16		IRC
R8,26			NOT USED			
T1	X		Transformer	126-3048		RS
		X	Transformer	126-3060		RS

Note: Resistor tolerance is ±10% unless otherwise specified

Table 6-1. Replacement Parts List (Sheet 3 of 3)

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